Surgical Management of Sternal Wound Dehiscence

Maria Pia Tocco, Eugenio Pompeo, and Giovanni Ruvolo

1 Introduction

Median sternotomy is the most common surgical approach in cardiac surgery and is also quite frequently employed in thoracic surgery.

The most frequent complication of this surgical access is wound infection eventually resulting in sternal wound dehiscence (SWD), which can be associated or not with sternal instability. Especially in open-heart surgery, it is responsible for significant morbidity, high mortality, additional multiple surgical procedures, prolonged hospitalization and increased cost of care.

Sternal wound dehiscence is a wound breakdown with or without clinical or microbiologic evidence of infection (Fig. 1) [1]. It can occur in the early postoperative days or after weeks or months.

In open-heart surgery, the incidence of SWD is about 0.9–20%, and the incidence of mediastinitis is 1–2% or somewhat higher. The variability in incidence can be addressed at least in part to the finding that a large number of wound complications occur after discharge, quite often in the rehabilitation centre, therefore, being sometimes missed by single-centre statistical analysis. Furthermore, there is a lack of a common comprehensive definition of postoperative SWD [1]. In fact, wound dehiscence, sternal wound

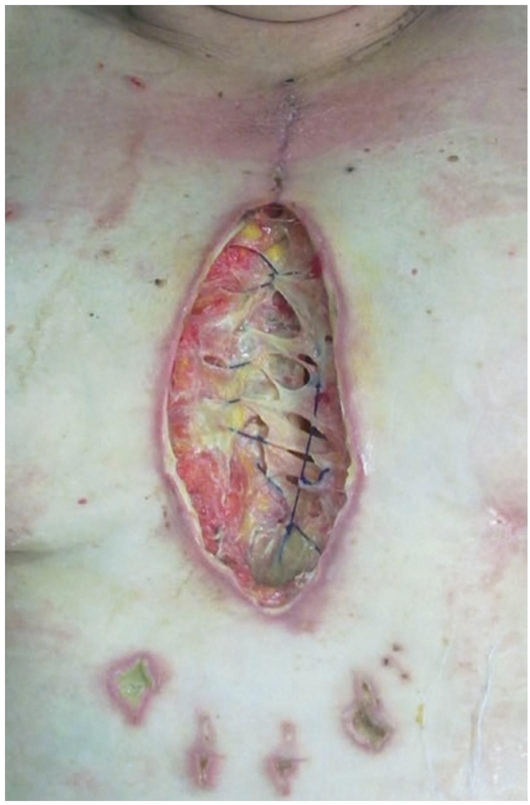

Fig. 1 A typical initial presentation of SWD in which skin dehiscence is evident whereas the status of the sternum is more difficult to be assessed

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infection, deep sternal wound infection, sternitis and mediastinitis are often used indifferently [1].

In the presence of a single or multiple skin breakdown along the sternal wound, sometimes it can be very difficult to understand whether the infection is superficial involving the subcutaneous tissue only or rather, constitutes the epiphenomena of a deeper underlying infection. The choice of the optimal treatment depends on the onset time, clinical presentation and radiologic features.

The aim of this chapter is to describe the preferred surgical methods which we selectively employed in this setting.

2 Pathogenesis

Median sternotomy presents several peculiar characteristics, which must be taken into account when considering pathogenetic factors of SWD:

1. The skin incision matches exactly to the sternal incision and hence allows the access to the mediastinum directly from the skin. For this reason all skin breakdowns should be considered potential door of access to the mediastinum. Sometimes, a limited wound dehiscence can be the "tip of an iceberg" of an underlying mediastinitis (Fig. 2).
2. The particular anatomy of the sternum, with the presence of the spongiosa bone characterized by wide inter-trabecular spaces containing red bone marrow, predisposes to the nesting of bacteria.
3. Anatomic variability of the internal mammary artery (IMA), in the absence of collateral blood flow, can be responsible for the loss of blood supply and hence of an impairment of the bone structure which can be more easily damaged by the sternal wires.
4. The presence of the ischaemia (or minor blood supply) of the bone due to the IMA harvesting can be responsible for a devastating sternum infection.
5. The immune deficiency due to compromising effects of cardiopulmonary bypass (CPB) on the immune system [2] can be responsible for the development of multidrug-resistant bacteria infections.

Whenever bacteria colonize the sternum, their eradication can prove extremely difficult for a number of reasons:

1. The trabecular bone structure of the sternum including the presence of the bone marrow.
2. A reduced blood supply due to previous harvesting of the IMA for bypass grafting.
3. The minor penetration of antibiotics in the bone due to sternal ischaemia, diabetes, obesity, etc.

The SWD can be expression of superficial or deep infection, and it can also be expression of

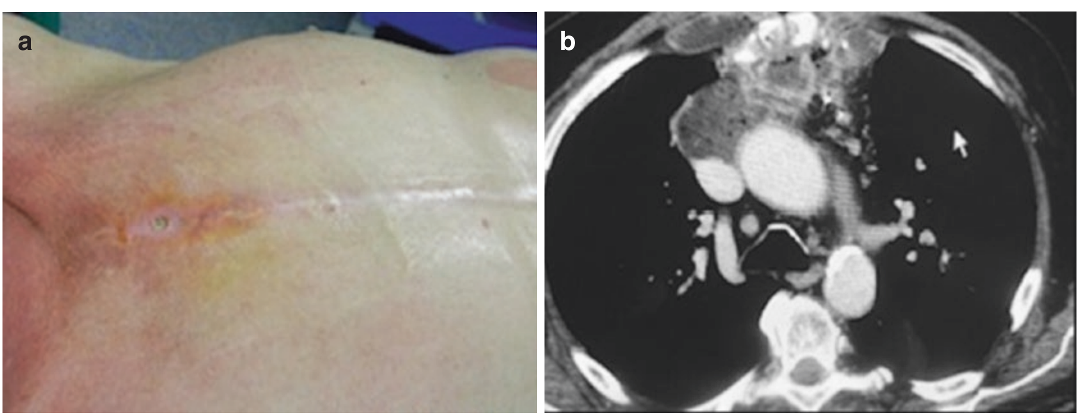

Fig. 2 Another case of SWD entailing minimal dehiscence of the skin wound and advanced mediastinitis with sternal dehiscence revealed by the CT scan

chronic osteomyelitis. The time of onset can orient the diagnosis. The mediastinitis occurs in the postoperative days, while chronic osteomyelitis presenting as sterno-cutaneous fistulas occurs after weeks, month or even years. However, in the presence of prosthetic material, mediastinitis as well may occur in a late stage even several years after surgery.

The sterno-cutaneous fistula presents as a draining sinus tract, in patient with a closed sternal wound [3]. It is often due to an incomplete eradication of the infection in the trabecular bone tissue. We have reported that CT imaging with 3D reconstruction algorithms of the bone can detect an area of osteomyelitis in correspondence of the fistula along the line of the sternotomy incision (Fig. 3) [4]. Sometimes, sternal osteomyelitis can be a result of a previous unrecognized or underestimated sternal wound infection. It can be also due to coagulase-negative staphylococci (CoNS) infection following postoperative SWD, which becomes the entrance door for bacteria colonizing the skin. In fact, in general the presence of CoNS in cultural samples is wrongly underestimated, and a treatment should be considered in some cases [3, 4].

For these reasons, it is very important not to underestimate any wound dehiscence. Rather, accurate monitoring of the inflammation parameters, clinical signs, radiologic features and the microbiological investigations can guide in obtaining a precise diagnosis, independent by the external appearance and extent of the wound dehiscence.

3 Risk Factors

Several studies have tried to assess the real incidence of this complication and have investigated the correlation with a large number of potential risk factors, which can be grouped into:

1. General factors such as age, gender, obesity, diabetes mellitus, chronic obstructive pulmonary disease (COPD) and smoking.

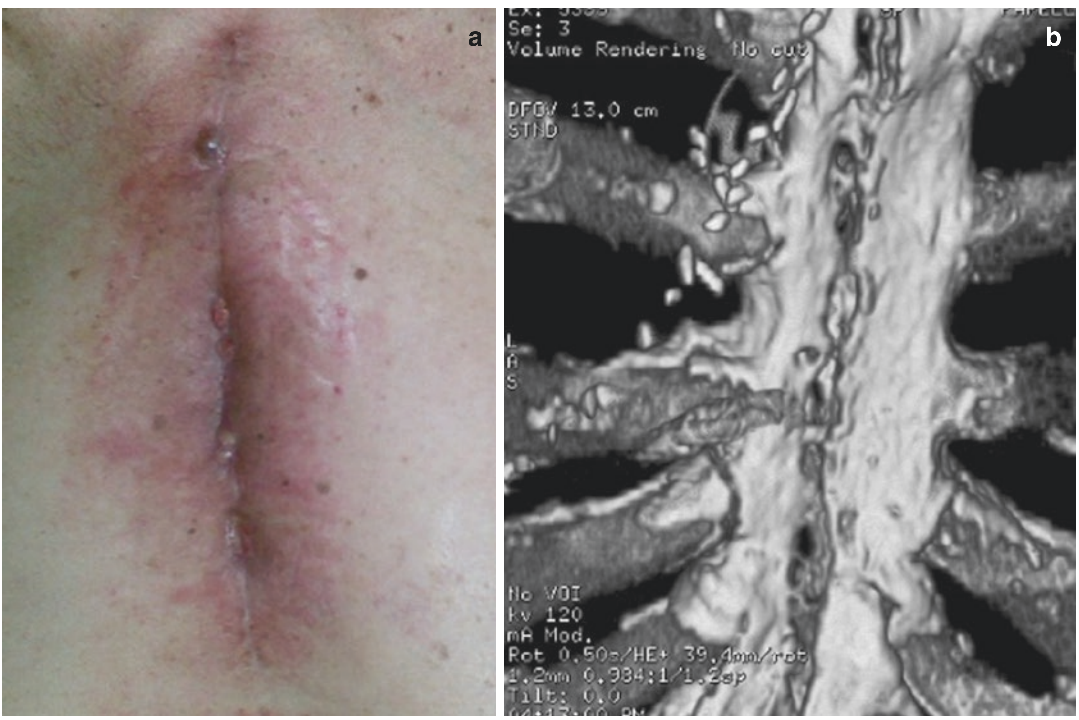

Fig. 3 Sternum-cutaneous fistula outlined by 3D chest CT

2. Procedure-related factors such as bilateral mammary graft, emergency operation, reoperation for bleeding, repeated blood transfusion, prolonged preoperative stay, duration of surgery, prolonged intensive care stay, prolonged postoperative mechanical ventilation, unilateral or bilateral pleurotomy, postoperative hyperglycaemia, off-midline sternotomy, use of bone wax and many others.

Overall, obesity and diabetes mellitus are recognized as the most important factors in the development of sternal wound infections [5].

COPD and smoking can facilitate the development of sternal instability due to excessive coughing and the consequent increased local fluid drainage, which in turn can become a broth for bacterial growth. In patients who are smokers, there is an increase of postoperative pulmonary complications and an impaired immune response.

Early tracheostomy can have an impact on the development of SWD although there are controversial opinions in this respect. Nonetheless, it is clearly evident that the mortality is higher when the infection occurs in patients who underwent tracheostomy postoperatively [6].

Nasal carriage of *Staphylococcus aureus* is considered another important risk factor in the pathogenesis of *Staphylococcus aureus*-related SWD [7].

Sternal ischaemia due to the IMA harvesting can play an important role in the pathogenesis of SWD. In fact, each hemisternum loses more than 90% of its blood supply after mobilization of the corresponding IMA [1]. This feature becomes particularly relevant, especially when both the IMAs are used for grafting and above all in the presence of risk other factors such as obesity, diabetes or COPD.

In this regard, a better preservation in the blood supply of the sternum has been reported to occur following harvest of the IMA according to the skeletonized technique as compared to the pedunculated one [8]. Moreover, the anatomical type of the arterial supply and in particular the presence or not of collateral branches have been considered an important issue. In fact, the arterial branches to the sternum originate either directly from the IMA or from the trunks that also give rise to the perforating branches and to the intercostal artery. Anatomical studies have shown that the common trunks can be of four main types:

1. Sternal/perforating
2. Sternal/intercostal
3. Perforating/intercostal
4. Sternal/perforating/intercostal

This variability of the anatomy as well as the presence of collateral flow to the sternum is considered important in the pathogenesis of sternal ischaemia, which facilitates the subsequent development of SWD [9].

An inadequate mediastinal drainage is another important factor [1]. In fact, the amount of liquid collected in the retrosternal space can spontaneously flow through the skin breakdown (Fig. 4).

Fig. 4 Outflow of fluid from an infected SWD

The fluid is a broth for bacterial growth and can cause infection and sternal instability.

Many authors have tried to classify SWD or mediastinitis on the basis of the risk factors and the clinical aspects. Gardlund et al. [10] reported a classification of mediastinitis based on the correlation between the microbiological aspects and the risk factors. These authors underlined the following points:

1. Mediastinitis due to coagulase-negative staphylococci, often associated with some risk factors such as obesity and COPD, usually presents sternal instability.
2. Mediastinitis due to *Staphylococcus aureus*, often caused by perioperative contamination, is often associated with stable sternum.
3. Mediastinitis due to gram-negative rods, often caused by spread from concomitant infection in other sites, is associated with stable and instable sternum in similar frequencies.

Another useful classification has been provided by El Oakley and Wright in 1996 [1] who classified the mediastinitis into four types based on the time of first presentation, the presence or absence of risk factors and the presence or absence of one or more failed therapeutic attempts (Table 1). Overall, classifications prove useful tools for the prevention of this complication and contribute to the challenging task of providing standardized criteria for choosing an optimal surgical approach.

Table 1 Classification of mediastinitis according to El Oakley and Wright [1]

Type I	Mediastinitis presenting within 2 weeks after operation in the absence of risk factors
Type II	Mediastinitis presenting at 2–6 weeks after operation in the absence of risk factors
Type IIIA	Mediastinitis type I in the presence of one or more risk factors
Type IIIB	Mediastinitis type II in the presence of one or more risk factors
Type IVA	Mediastinitis type I, II or III after one failed therapeutic trial
Type IVB	Mediastinitis type I, II or III after more than one failed therapeutic trial
Type V	Mediastinitis presenting for the first time more than 6 weeks after operation

4 Surgical Management

The management of SWD involves a spectrum of different procedures. The choice of the optimal method must be based on the clinical and radiological features, on the time of onset as well as on the experience of the centre.

The clinical presentation is very important and is associated with the following main aspects:

1. Presence of purulent or serous drainage from the wound breakdown, fever and the presence or not of swelling and redness, chest pain, sternal instability and high serum levels of the reactive protein C and of other inflammatory parameters.
2. Contrast computed tomography features showing an involvement of the mediastinum and eventually of the sternum.

The fundamental aim of any treatment modality is to clean the wound and then, once the infection has been eradicated, to proceed with the wound closure.

In the last decades, many procedures including surgical revision, closed suction catheters with or without a continuous mediastinal irrigation, wound debridement and open dressing with delayed closure and aggressive early debridement followed by reconstructing plastic procedures using omental or muscle flaps have been described.

In recent years, the use of vacuum-assisted closure (VAC) has been increasingly adopted [11–13]. We also employ it as first choice method in the treatment of superficial and deep wound infections, as a bridge to would closure [14]. Use of VAC for treatment of SWD was first described in 1997 by Morikwas and Argenta [15, 16] and is based on prolonged application of a continuous negative pressure within the wound region [11]. This is usually achieved following accurate surgical debridement by using a polyurethane foam dressed into the entire wound (Fig. 5), which is sealed with a transparent adhesive film (Fig. 6) and then connected by a tube to a pump that gen-

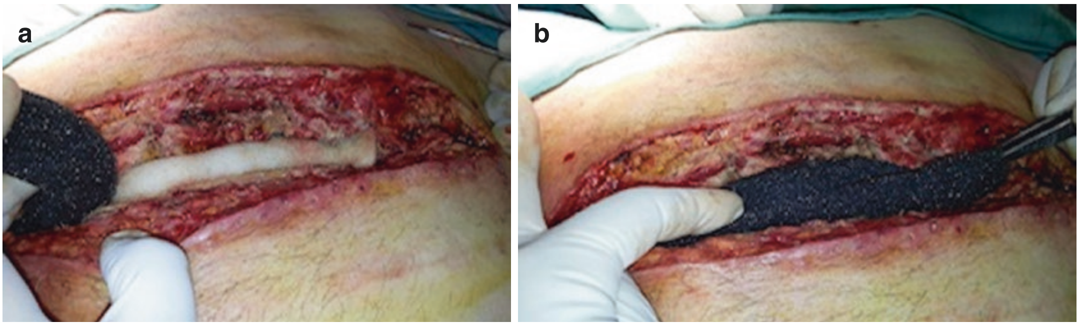

Fig. 5 Polyurethane foam dressed into the sternal wound

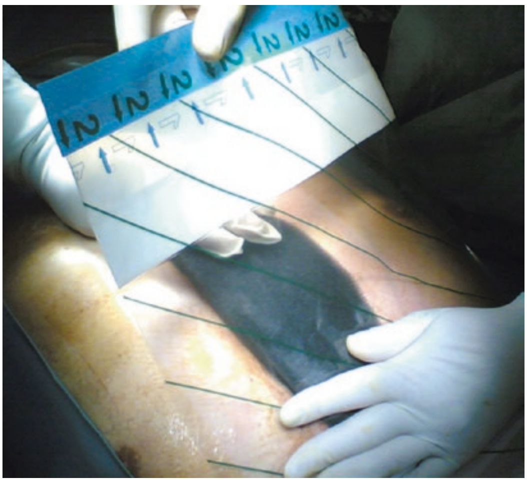

Fig. 6 Sealing of the dressed wound by a transparent adhesive film

erates a continuous negative pressure (usually −125 mmHg) (Fig. 7). A canister is placed in a portable pump to collect the fluid draining from the wound.

The physiologic mechanism of action underlying this method is that the negative pressure created at the wound site increases the local blood flow allowing:

1. Better local penetration of the antibiotics
2. Reduction in bacterial colonization rates
3. Decrease of the local oedema
4. Optimal drainage of the wound

As a result, the production of the granulation tissue is stimulated, and progressive healing of the wound can be facilitated eventually allowing the definitive surgical closure.

Fig. 7 Negative-pressure generating pump

4.1 Closed Redon Catheter Drainage

In case of mediastinal inadequate drainage, sometimes, in the presence of an early SWD from which serous or corpuscolated fluid comes out, it is possible to place a closed Redon drainage in the subcutaneous tissue of the wound to drain all the liquid and close the wound breakdown with a suture. In fact, the Redon drainage makes it possible to keep dry the wound, whereas wound suturing can avoid the entrance of bacteria from the skin breakdown.

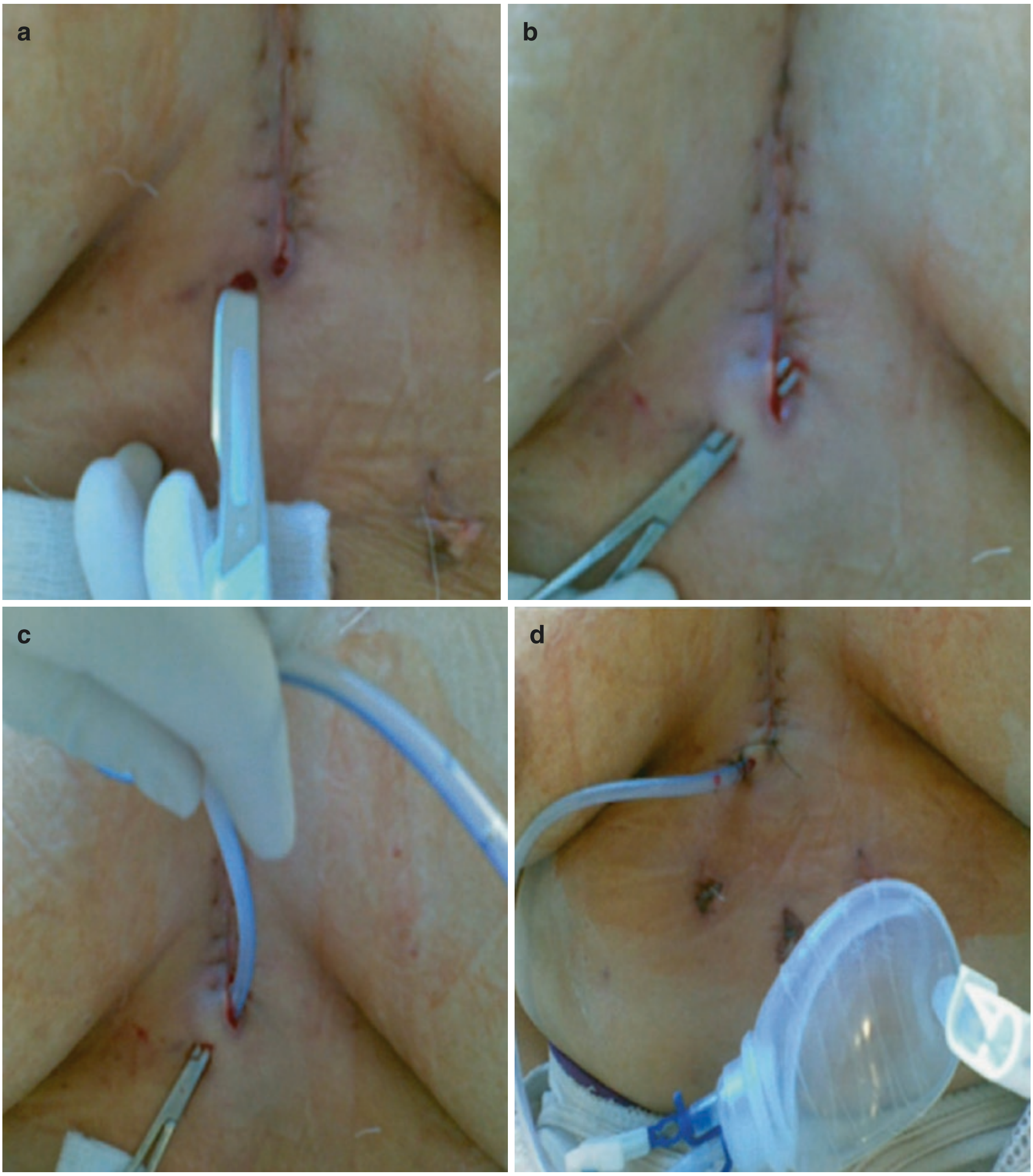

Fig. 8 Placement of multiple subcutaneous Redon drainages

The technique is very easy. We commonly perform a small opening in the lower part of the wound to insert the drainage, which it then pushed as far as possible (Fig. 8). The drainage is left in situ for several days until when the daily amount of drained fluid decreases significantly. Culture examinations of the liquid should be performed periodically during this type of treatment.

4.2 VAC therapy

In case of mediastinal involvement, the surgical approach must be more aggressive. In our experience, all patients are treated by VAC in order to eradicate the infection before performing the sternal closure.

All the patients undergo initial surgical debridement with the removal of all sternal wires, all necrotic or devitalized tissue, the exposed cartilages and, whenever present, of the bone fragments. Any sharp sternal edges are also eliminated to avoid the risk of heart injury. After collecting tissue samples for microbiological investigation, the wound is washed with H_2O_2 and with 1% diluted povidone-iodine solution.

In the presence of sternal instability, we first protect the heart from mechanical injury with a special nonadhesive white sponge, which is positioned under the sternal edges. Afterwards, a black sponge, which can be cut in different shapes, is positioned between the sternal edges to keep clean the bone and the deep tissues. This measure aids also to give stability to the sternum. Finally we insert another layer of sponge to cover the entire wound (Fig. 5), and we seal all the wound area by applying a transparent film (Fig. 6). The sponges are changed twice a week in the operating room under mild sedation. Microbiology culture samples are periodically collected to evaluate changes in bacteria colonies and antibiotic susceptibility to verify the adequacy of the antibiotic therapy [16]. When the cultures become negative, the wound looks viable and serum levels of inflammatory parameters have lowered, surgical wound closure can be performed [17].

The technique employed for the wound closure can vary, depending on the status of the sternum.

If the bone is deemed in good condition, it is possible to re-suture the sternum directly using steel wire, Nitinol clips or titanium-made sternal devices.

When the sternum is found in a bad condition due to the extensive debridement or to the presence of multiple transversal fractures, the use of muscle flaps is considered more appropriate for closing the chest.

4.3 Thermo-reactive Nitinol clips

The Nitinol clips (Flexigrip, Praesidia srl, Bologna, Italy) are made of nickel and titanium alloy (Nitinol). They have thermo-reactive properties since cooling allows the transformation of Nitinol from austenite into martensite, which is a soft material, whereas heating allows the reverse of the cycle transforming martensite to austenite, which is a hard material.

Fig. 9 Nitinol clip

Before being implanted, these clips are thus cooled in order to allow a deformation which facilitates their insertion in the sternum sides. Once the clips are positioned, a warm gauze is placed above the clips, allowing them to contract and to return to the initial shape due to a preformed shape memory, eventually pulling together the sternal edges (Fig. 9).

The clips have different sizes and can be inserted through a hole made by the electrocautery in the intercostal space close to the sternal rim. Three clips are generally sufficient to achieve good sternal stability. If the sternum presents some fractures, some screwed plates are inserted in association with the clips.

The main advantage of Nitinol clips is that their application is rapid and noninvasive because there is no need to free the posterior face of the sternum from the mediastinal structures (Fig. 10) and the clips can be inserted in the parasternal space without any dissection of the substernal tissue [17–20]. As a result we consider this method particularly useful following the use of VAC, when rewiring can be difficult because the mediastinal structures are likely to become firmly adherent to the posterior aspects of the sternum and surgical dissection might be associated with a high risk of major bleeding.

4.4 Flap Reconstruction

When the sternum is in bad condition due to extensive debridement or to the presence of several bone crushes, muscle or omental flaps can be

Fig. 10 Complete sternal dehiscence closure by Nitinol clips

used to close the chest. In recent years, the use of VAC has reduced the use of the great omentum or the rectus abdominis muscle flap because of a progressive reduction of the wound width and in depth by these less invasive methods. Furthermore, the use of the rectus muscle has a high risk of failure when the IMA has been already employed for the grafting. In our experience, in most of instances, the use of pectoralis muscle flap is adequate to close the gap between the sternal edges and to ensure a good chest closure. Moreover, Zeitani and coworkers [21, 22] have found that in patients with chronic complex SWD, the use of pectoralis muscle flap repair minimizes the occurrence of paradoxical motion of the chest wall when compared to sternal rewiring, eventually leading to better respiratory function and clinical outcomes including less pain and lower dyspnoea grade during the follow-up.

The surgical technique is easy and safely feasible without the need of any further skin incision. The dissection is performed on one side using the diathermy, starting from the sternal edges and proceeding by exposing the cartilages and the ribs. Laterally, the dissection is carried to the anterior axillary line. Superiorly, dissection manoeuvres are interrupted at the level of the clavicle taking care not to cut the pectoralis branch of the thoraco-acromial artery that supplies the pectoralis flap. Inferiorly, the attachment of the muscle fibres on the cartilages of the sixth and seventh rib is divided, and the aponeurosis of the abdominis external muscle is exposed. At this point the flap is freed laterally, inferiorly and medially, and it can be elevated off the chest wall (Fig. 11). Then, it can be advanced to the midline avoiding any tension, and it can be transposed into the mediastinum to fill in the space between the sternal edges. Equivalent manoeuvres are performed on the contralateral side. Absorbable and non-absorbable sutures can be alternatively placed to approximate the flap to the sternum and then the muscle flaps together (Fig. 12). Six Redon drainages are positioned

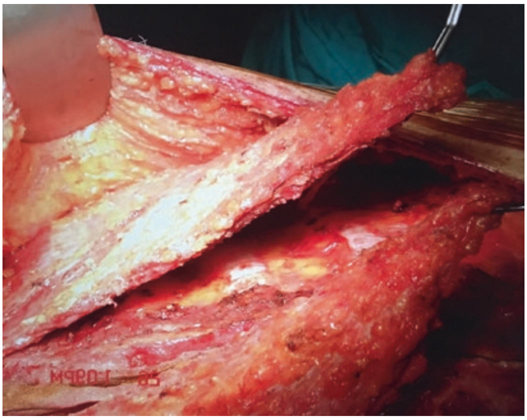

Fig. 11 Pectoralis muscle flap which is freed and elevated off the chest wall

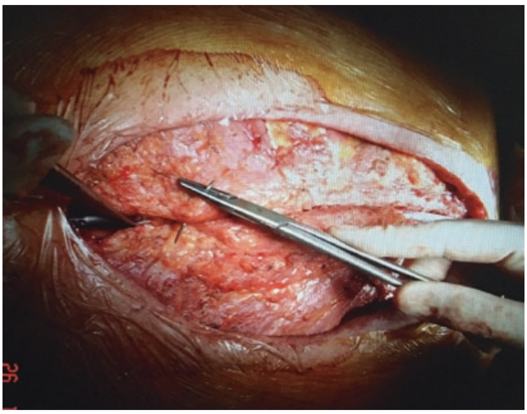

Fig. 12 Transposition of the flap into the mediastinum to fill in the space between the sternal edges

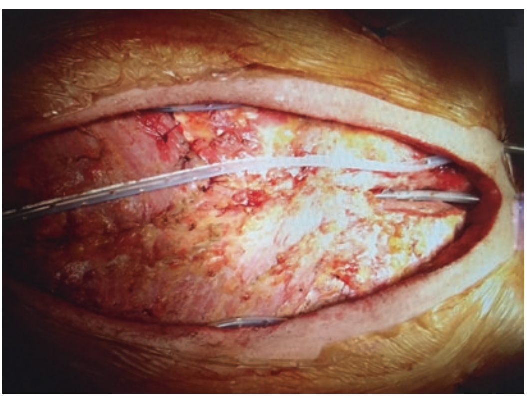

Fig. 13 Multiple Redon drainages are placed both below and above each flap

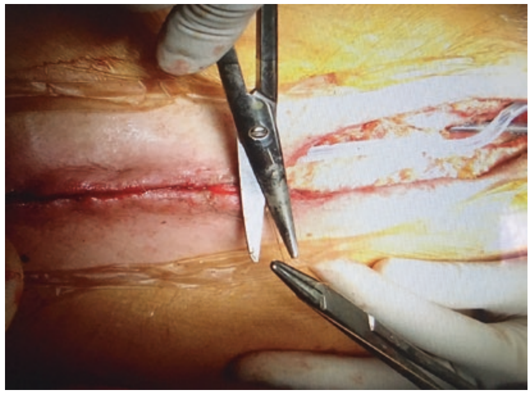

Fig. 14 Final suturing of the skin and subcutaneous tissue by absorbable sutures

either under or above each flap, in the mediastinum and above the flaps along the midline (Fig. 13). The skin and subcutaneous tissue are closed with absorbable sutures (Fig. 14).

Conclusions

Surgical management of SWD is not univocal and entails different options, which can be employed according to a tailored stepwise strategy of treatment following accurate assessment of clinical, radiological and microbiological features. As a rule an early aggressive treatment seems to offer the best chance of cure to any type of SWD.

The use of a closed Redon drainage and/or early debridement followed by the VAC therapy can guarantee, according to our experience, the best results in achieving a complete eradication of bacterial infection and constitute a mainstay of treatment since it helps prevent infection relapses and failures of muscle flaps repair. Before starting the VAC therapy, we consider important to remove all the steel wires to prevent the development of sterno-cutaneous fistula.

In the presence of clinically evident mediastinitis, an early debridement followed by the use of VAC is the optimal treatment option in terms of final outcome and overall survival.

The closure of the sternum must be delayed until when the cultural samples become negative.

In our experience, following VAC therapy, a direct closure of the sternum can be performed using Nitinol clips and/or screwed plates, to minimize risks of damaging the mediastinal structures. On the other hand, if the sternum is severely damaged and multi-fractured, use of pectoralis muscle flaps is a preferable option to assure an optimal repair and a satisfactory stability of the sternum with minimized risks of paradoxical motion of the chest during ventilation.

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